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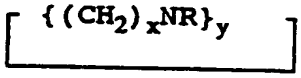

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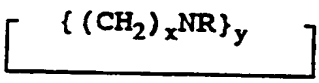

(II)

(57) Abstract

The present invention relates to a new polyazamacrocyclic compound or a salt thereof and its uses as a tissue specific chelator. The compound has formula (I), where x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y; y is 3 or 4; R is $(CH_2)_ZP(=O)OR^1OR^2$; R^1 is H or CH_3; R^2 is C_nH_{1+2n}; n is 4 to 6; z is 1 to 3. In one important embodiment, this compound may be complexed with a metal to be a plyazamacrocyclic compound-metal complex having formula (II), where r is 2 or 3; and M is a metal ion, including a lanthanide, a heavy metal, or a radionuclide metal.

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DESCRIPTION
POLYAZAMACROCYCLIC COMPOUNDS FOR COMPLEXATION OF METAL IONS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to compositions and methods for enhancing contrast in imaging internal structures and functions of living subjects.

Imaging Modalities

Imaging of internal structures and functions of living subjects may be accomplished by applying electromagnetic radiation from external sources (as in conventional x-rays and computerized axial tomography) or internal sources (as in PET or positron emission tomography and radionuclide scans). Use of ionizing radiation is avoided in imaging with nuclear magnetic resonance (NMR) and untrasonography, making these methods advantageous for many applications.

Whatever the imaging modality, consideration is given to means of increasing image contrast through localization of contrast agents in the region to be imaged. Such agents are frequently metals which emit, absorb, or scatter energy or, as in the case with NMR agents, increase the image signal strength locally. For best effect, agents must be localized. This may be accomplished, for example, by direct injection of contrast agent (as in myelograms or retrograde urethrograms), through metabolic uptake of an agent (as in PET), and by conjugation of contrast agents with monoclonal antibodies which tend to accumulate in certain tissues. The latter process in particular has been used

in NMR image enhancement with chelated metal ions. Though well known, the process has several shortcomings:

1 - preparation of the antibody is complex;
2 - diminished immunoreactivity of the antibody occurs following conjugation;
3 - there is limited uptake of the conjugate by the target tissue; and
4 - there may be unfavorable interactions between the chelated ion and the antibody.

Because of the advantages of NMR imaging (good resolution and avoidance of ionizing radiation), an NMR contrast agent capable of greater localization would be clinically important. Such an agent would offer significant advantages over contrast agents of the prior art.

NMR Contrast Agents

The quality of the images obtained from an NMR scan is based on two properties: the proton densities of the various tissues and differences in proton relaxation rates. The proton density of tissues cannot be readily altered. Proton relaxation rates can be adjusted by adding a paramagnetic relaxation agent, more commonly known as a "contrast agent." Contrast agents enhance the contrast in NMR images between magnetically similar but histologically dissimilar tissues.

Gadolinium, which has strong paramagnetic properties because of its seven unpaired electrons, has been tested as a contrast agent. It has a large magnetic moment which efficiently relaxes magnetic nuclei and increases tissue contrast in the region of the gadolinium.

One drawback of gadolinium as a contrast agent is its toxicity to animals, although a possible remedy for

this problem is incorporation of gadolinium in a compound that would pass through the body and be excreted without releasing toxic gadolinium ions. Unfortunately, the rare earth elements (including gadolinium) do not form stable covalent bonds with organic molecules, so such molecules can decompose *in vivo* and release the toxic ions.

Thus, there is a need for effective contrast agents which avoid the toxicity problems inherent in using gadolinium or another metal ion. Further, it is desirable that a contrast agent control or influence the distribution of chelated ions in the body.

A even more desirable approach to the site-specific delivery of metal ions would be through use of stable chelates having inherent affinity for various tissue types. Inherent tissue affinity built into the organic chelating agent through modifications in both ionic charge and degree of lipophilic character would offer substantial advantages over currently available agents.

SUMMARY OF THE INVENTION

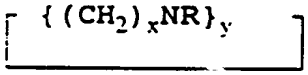
The present invention relates to a series of new phosphorous-containing triaza- and tetraazamacrocyclic chelators which have inherent affinity for certain tissues. Following intravascular injection, chelates comprising these compositions preferentially accumulate in certain tissues, depending on the time after injection. In particular, 1,4,7,10 tetraazacyclododecane-1,4,7,10-tetra(methylenephosphonate monobutyl ester) has a high affinity for liver tissue and the gastrointestinal tract (in that order). Chelates comprising this agent are thus suitable for liver imaging because of the lipophilic character imparted by the ester

functionality. Such agents are not metabolized, and eventually pass out of the body via the urine or feces.

While the monobutyl ester above appears well adapted for liver imaging, analogous alkyl esters have also been considered. Monopentyl esters are nearly as good for liver imaging, but monooctyl esters have the disadvantage of very low aqueous solubility. Monopropyl esters, on the other hand, may be used for liver imaging but are less efficient because a substantial portion of the agent is rapidly lost to the kidneys; monoisopropyl esters would behave similarly. Hence, the most preferred embodiment is that described above with monobutyl esters.

For use with NMR, compositions of the present invention must be chelated with a metallic element. While the element is preferably of the rare-earth series (preferably gadolinium), those skilled in the art will recognize that other metallic ions might also be useful for imaging. For example, other metal chelates (e.g., chelates of radionuclides or heavy metals) may be used for imaging by scintigraphy, x-radiation, and analogous imaging methods where changes in local tissue parameters can increase image contrast. Depending on the metal ion preferred for a particular contrast agent application, either triaza- or tetraaza- compounds of the present invention may be selected as chelators.

Chelators of the present invention have the formula



where

x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;

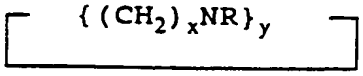
y is 3 or 4;

R is $(CH_2)_zP(=O)OR^1OR^2$;

R^1 is H or CH_3;

R^2 is butyl, pentyl or hexyl; and
z is 1 to 3.

In one important embodiment, this compound may be complexed with a metal to be a polyazamacrocyclic compound-metal complex having the formula



where
x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;
y is 3 or 4;
R is $(CH_2)_ZP(=O)OR^1OR^2$;
R^1 is H or CH_3;
R^2 is butyl, pentyl or hexyl;
z is 1 to 3;
r is 2 or 3; and
M is a metal ion.

The y designation characterizes the compound as triazamacrocyclic or tetraazamacrocyclic. The x is preferably 2, although 3 is feasible under many circumstances. Combinations of p 2(s) and q 3(s) for x are of course readily produced but the total of p + q must be y for the number of units in the polyaza macrocycle. H or CH_3 for R^1 are believed equivalent in use.

In a preferred embodiment of either the compound or its metal complex y is 3, p is 1 and q is 2 or p is 2 and q is 1.

In another preferred embodiment of the compound or its metal complex, y is 4, p is 1 and q is 3, p is 2 and q is 2 or p is 3 and q is 1 and z is most preferably 1. n is preferably 2.

In a more preferred embodiment x is 2, y is 4, z is 1, R^1 is H and R^2 is butyl.

In another preferred embodiment X is 2, y is 3, z is 1, R^1 is H and R^2 is butyl.

The M^{+r} is preferably a paramagnetic lanthanide, although other divalent or trivalent metal ions, including radionuclides and heavy metals, may also be so complexed.

In one important application, the present invention involves a method for enhancing a magnetic resonance image of a subject. This method comprises administering to the subject a polyazamacrocyclic compound-metal complex having the formula

$$\left[\{(CH_2)_xNR\}_y\right]M^{+r},$$

where

x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;
y is 3 or 4;
R is $(CH_2)_zP(=O)OR^1OR^2$;
R^1 is H or CH_3;
R^2 is butyl, pentyl or hexyl;
z is 1 to 3;
r is 3; and
M is gadolinium.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 schematically illustrates the structure of NOTPME (where R is CH_2CH_3 and R^1 is H).

Figure 2 schematically illustrates the structure of DOTEP.

Figure 3 schematically illustrates the structure of DOTPMB.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

EXAMPLE 1

Triazamacrocyclic Compounds

NOTPME Synthesis

Materials

1,4,7-triazacyclononane, paraformaldehyde, diethylphosphite, and activated carbon Darco G-60 were purchased from Aldrich Chemical Company. $MgSO_4$ was from Mallickrodt, sodium hydroxide, and benzene from J. T. Baker, and diethylether from Fisher Scientific. All chemicals were of highest purity and were used without further purification. Solutions of $ZnCl_2$, $GdCl_2$, $MgCl_2$ and Ca Cl_2 were standardized complexometrically.

Synthesis of NOTPME

1,4,7-Triazacyclononane (1.91 g, 14.71 mmol) and diethylphosphite (7.018 g, 16.94 mmol, 15% excess) were dissolved in 125 ml of benzene and heated to reflux. Anhydrous paraformaldehyde (1.727 g, 30% excess) was added in small portions to the above refluxing mixture while the benzene-water azeotropic mixture was removed by distillation. After the addition of paraformaldehyde was complete, the entire solution was boiled for 30 minutes and then evaporated to obtain a yellow viscous oil. The oil was dissolved in 150 ml anhydrous diethylether and dried with anhydrous $MgSO_4$ overnight. $MgSO_4$, along with a white precipitate which formed, were filtered off and discarded. The filtrate was decolorized with activated carbon and filtered. The filtrate was evaporated in vacuum to obtain a viscous oil of 1,4,7-triazacyclononane-N,N',N''-tris(methylenephosphonate

diethylester) (NOTPDE). Pure NOTPDE was obtained in 96% yield (9.21 g, 14.17 mmol) and was used for the synthesis of NOTPME (structure shown in Figure 1) without further purification. ^1H NMR data of NOTPDE in $CDCl_3$ (TMS at zero) are as follows: δ (ppm) : 1.33 (t, 18H, $-CH_3$), 2.97 (s, 12H, $N-CH_2$), 3.00 (d, 6H, $P-CH_2$), 4.13 (p, 12H, $O-CH_2$).

9.20 g of NOTPDE (14.15 mmol) was mixed with 2.50 g of NaOH in 9 ml H_2O) and after 2 hours the entire reaction mixture was boiled until a clear solution was obtained (approximately 5 minutes). The solution was cooled to room temperature and was allowed to stand overnight. The crystals formed were filtered off from the viscous mother liquor using a pressure filter funnel with a coarse porosity grade filter disc. The crystals were washed once with cold absolute ethanol, three times with absolute ethanol-diethylether (1:1) mixture and finally with diethyl ether. The crystals of Na_3NOTPME were dried in dry nitrogen stream at 25°C for 2 hours. Traces of H_2O and ethanol were removed upon vacuum drying (10 mm Hg) NOTPME for 5 hours at 50°C. Pure NOTPME thus obtained were white crystals, very hygroscopic, readily soluble in H_2O, and fairly soluble in chloroform. The yield of pure NOTPME was 40.8% (3.24 g, 5.77 mmol).

^1H NMR (D_2O, HDO peak set as reference at 4.90 ppm), δ (ppm): 1.23 (t, 9H, $-CH_3$), 2.54 (s, broad, 6H, $P-CH_2$), 2.79 (s, broad, 12 H, $N-CH_2$), 3.91 (p, 6H, $O-CH_2$).

EXAMPLE 2

Tetraazamacrocyclic compounds

DOTEP Synthesis

DOTEP, shown in Figure 2, was prepared as follows. 2 ml of dichloroethylphosphine was slowly mixed with ice to form the corresponding ethylphosphinic acid. After

warming to room temperature, 390 mg of 1,4,7,10-tetraazacyclododecane tetrahydrochloride (cyclen.4HCl) (Parrish Chem. Co., Ogden, Utah) was added and the mixture heated to boiling under a nitrogen atmosphere. A solution containing 157 mg of paraformaldehyde dissolved in 10 ml of 6M HCl was added at a rate of 0.5 ml/hr, while the mixture continued to reflux. The final mixture was refluxed an additional 4 hours then cooled to room temperature. This solution was concentrated under vacuum to a viscous oil, redissolved into 6 ml of water and loaded onto a DOWEX 50Wx4 (hydrogen form) cation exchange column (7.5 ml bed volume). The column was washed to neutrality with water and the product eluted with 60 ml of 0.66 M HCl. The fractions containing DOTEP were combined, evaporated, redissolved in absolute ethanol and evaporated to a white solid. This solid was dispersed into anhydrous ether, filtered off, pre-dried under nitrogen and dried under vacuum at 60-70°C to yield a white, very hygroscopic solid (360 mg, 44% yield). This solid was stored in sealed ampoules. Elemental analysis and potentiometry shows the solid to be DOTEP.2HCl

EXAMPLE 3

Tetraazamacrocyclic compounds

DOTP Dibutyl Ester Synthesis

Tetraaza-12-crown-4·4HCl (1 g, 3.14×10^{-3} mol) was dissolved in water and the pH adjusted to 9.0 using 1M NaOH. The solvent was evaporated and the residue dried under vacuum for 1 hour. Formaldehyde (6.6 mL of 37% solution, 7.15 g, 0.24 mol) was added and the solution stirred for 30 minutes at room temperature. Dibutyl phosphite (5.10 mL of 96% purity, 0.025 mol) was then added and the reaction mixture stirred for 15 hours at room temperature (dipentyl and dihexyl phosphite are so used to produce dipentyl and dihexyl esters respectively). The resulting mixture consisted of two

layers. The bottom layer was mostly excess formaldehyde, as indicated by ^{13}C NMR. The upper layer contained the product and excess phosphite. This layer was separated, concentrated and dried under vacuum for 1 hour. The resulting syrup was loaded onto a silica-gel column (2.5 x 11 cm). The excess phosphite was washed away with methylene chloride (250 mL). The product was eluted with 5% methanol in methylene chloride. 20 mL fractions were collected and monitored by TLC. The fractions containing the product were combined, concentrated, and dried under vacuum,. A pale yellow oil was obtained in 75% yield (2.34 g). ^1H NMR ($CDCl_3$): 0.87 (t, J=7.3, 6H), 1.33 (m, J=7.3, 4H), 1.60 (p, J=7.3, 4H), 3.18 (br s, 4H), 3.39 (d, J=8.5, 2H), 4.03 (m, J=7.3, 6.1, 4H). ^{13}C NMR ($CDCl_3$): 11.3 (s), 16.5 (s), 30.3 (d, J=5.9), 47.3 (d, J=148), 50.0 (br s), 63.8 (d, J=7.3).

EXAMPLE 4

Tetraazamacrocyclic compounds

DOTP Monobutyl Ester (DOTPMB) Synthesis

The dibutyl ester was suspended in 1M KOH (20 mL). The mixture was stirred at 85°C for 17 hours and then at 106°C for 9 hours. The solvent was evaporated and the sample dried under vacuum for 1 hour. Methylene chloride (40 mL) was then added and the remaining solid KOH crushed as much as possible. The solvent was again evaporated and this procedure repeated another two times. The solvent was evaporated and the residue dissolved in methanol (60 mL). The mixture was filtered and then concentrated to a syrup under vacuum. Methylene chloride (80 mL) was added and the mixture filtered. The solvent was evaporated and the residue dried under vacuum to yield a white solid in 71% yield. ^{13}C NMR (D_2O; ref. dioxane at 67.0 ppm): 13.5, 18.9, 32.9 (d, J=5.9), 50.7 (d, J=140.6), 51.5 (br s), 64.6 (d, J=5.9).

EXAMPLE 5
Biodistribution of Gd-DOTPMB

Complexation and Biodistribution

A complex of DOTPMB (Figure 3) and Gd complex (0.012M based on metal, 2:1 ligand/metal ratio) was prepared and spiked with tracer quantities of Gd-159. Complexation was determined to be greater than 99% by standard analytical methods described in earlier reports. Two Sprague-Dawley rats were then injected with the complex at a 0.05 mmol/kg level. The animals were sacrificed after 30 minutes and dissected for biodistribution data (Tables I and II); actual counts obtained from various tissues are shown in Table II. At the end of this time period, an average of 58% of the injected dose was found in small intestine (see entry for SM INTES in Table I). A similar experiment performed with a third rat yielded 52% in small intestine (Tables III and IV); actual counts obtained from various tissues are shown in Table IV. The bulk of the remaining activity in each case was eliminated via the renal system (Tables II and IV).

In order for localization to occur in the small intestine, the complex must first pass through the liver. Thus, since liver activity at the 30 minute time point (1%) was minimal (see *e.g.*, Table I), the peak of liver localization passed within the prior 30 minutes. This is evident in an example of biodistribution 15 minutes after administration of chelated tracer, which is documented in Tables VIII and IX. Although by 15 minutes the peak of liver localization had passed for mouse 1, with 4% in the liver and 88% in the small intestine, mouse 2 still had a significant liver concentration (66%) at the 15 minute point. These animal models suggest that imaging within 15 minutes after administration of chelated tracer will be necessary for best definition of the liver. The

following test description supports that conclusion. Higher doses would, of course, lengthen the time of liver localization at concentrations sufficient to substantially enhance liver imaging.

Gamma Imaging of DOTPMB

A Sm(153)-DOTPMB complex was prepared as described above for gamma imaging of a Sprague-Dawley rat. Images were acquired at one minute intervals over a 16-minute period. The image sequence revealed concentration of the chelate in liver within one minute following injection. The complex is then rapidly transported from the liver to the stomach and small intestine. Tables V, VI and VII contain data taken at 1 hour, 24 hours and 72 hours after injection, showing movement of the agent from stomach and intestine to feces.

TABLE I

TIME: 30 Minute Biodistribution

DATE LIGAND METAL COMMENTS

8/6/91 DOTPMB-K, Gd-159, 99% Complexation

4:1, LIG:MET Molar Ratio, (Metal = 3x10-4M)

	%DOSE/GRAM			
	RAT 1	RAT 2	AVERAGE	+/-
WEIGHT	216.72	228.17	222.45	8.096
BONE	0.019	0.006	0.01	0.009
TAIL	0.077	0.068	0.07	0.007
LIVER	0.114	0.069	0.09	0.032
KIDNEY	0.169	0.126	0.15	0.031
SPLEEN	0.011	0.021	0.02	0.007
MUSCLE	0.007	0.005	0.01	0.001
BLOOD	0.021	0.017	0.02	0.003
HEART	0.014	0.000	0.01	0.010
LUNG	0.126	0.023	0.07	0.073
BRAIN	0.002	0.003	0.00	0.000
0.000 = NO ACTIVITY DETECTED				
	DOSE			
BONE	0.281	0.106	0.193	0.124
TAIL	0.212	0.191	0.201	0.015
LIVER	1.234	0.755	0.994	0.339
KIDNEY	0.392	0.299	0.346	0.066
SPLEEN	0.009	0.011	0.010	0.002
MUSCLE	0.658	0.506	0.582	0.108
BLOOD	0.299	0.250	0.274	0.035
HEART	0.011	0.000	0.006	0.008
LUNG	0.158	0.029	0.094	0.091
BRAIN	0.004	0.004	0.004	0.001
STOMACH	0.574	0.530	0.552	0.031
SM INTES	80.304	36.405	58.354	31.041
LG INTES	0.591	0.433	0.512	0.112

TABLE II (see legend for Table I)

DATA	COUNTS	ORGAN	N ENTER WT	BCKG COR	%DOSE/G	% DOSE
1		Std A	X Rat 1 Wt	0		
1		Std B	X 216.72	0		
2	414838	Std C	av 414404.5	414405		
3	480	Bone	0.60	47	1.87E-02	2.81E-01
4	1311	Tail	2.74	878	7.73E-02	2.12E-01
5	5546	Liver	10.86	5113	1.14E-01	1.23E+00
6	2058	Kidney	2.32	1625	1.69E-01	3.92E-01
7	469	Spleen	0.75	36	1.14E-02	8.57E-03
8	478	Muscle	1.52	45	7.06E-03	6.58E-01
9	576	Blood	1.62	143	2.12E-02	2.99E-01
10	481	Heart	0.82	48	1.40E-02	1.15E-02
11	1088	Lung	1.25	655	1.26E-01	1.58E-01
12	449	Brain	1.62	16	2.31E-03	3.74E-03
13	2811	Stomach		2378		5.74E-01
14	333215	Sm Intes		332782		8.03E+01
15	2883	Lg Intes		2450		5.91E-01
16	150310	Urine		149877		3.62E+01
17	400	Urine		0		0.00E+00
18	428	Urine		0		0.00E+00
19	443	BKG	228.17	WT Rat 2		
20	451	Bone	0.67	18	6.30E-03	1.06E-01
21	1225	Tail	2.82	792	6.77E-02	1.91E-01

DATA	COUNTS	ORGAN	N ENTER WT	BCKG COR	%DOSE/G	% DOSE
22	3561	Liver	10.96	3128	6.89E-02	7.55E-01
23	1674	Kidney	2.38	1241	1.26E-01	2.99E-01
24	480	Spleen	0.53	47	2.12E0-02	1.12E-02
25	469	Muscle	1.66	36	5.16E-03	5.06E-01
26	559	Blood	1.80	126	1.68E-02	2.50E-01
27	430	Heart	0.85	0	0.00E+00	0.00E+00
28	554	Lung	1.28	121	2.27E-02	2.91E-02
29	452	Brain	1.55	19	2.88E-03	4.46E-03
30	2629	Stomach		2196		5.30E-01
	151297	Sm Intes		150864		3.64E+01
	2229	Lg Intes		1796		4.33E-01
	116731	Urine		116298		2.81E+01
	901	Urine		468		1.13E-01
	423	Urine		0		0.00E+00
	424	BKG		0		

BKG AVG = 434

TABLE III

TIME: 30 Minute Biodistribution

DATE	LIGAND	METAL	COMMENTS
8/6/91	DOTPMB-K,	Gd-159,	99% Complexation

4:1, LIG:MET Molar Ratio, (Metal = 3x10-4M)

	%DOSE/GRAM RAT 3
WEIGHT: 235.14	
Bone	0.006
Tail	0.013
Liver	0.016
Kidney	0.121
Spleen	0.000
Muscle	0.000
Blood	0.000
Heart	0.000
Lung	0.009
Brain	0.004
0.000 = No Activity Detected	
Bone	0.109
Tail	0.038
Liver	0.196
Kidney	0.303
Spleen	0.000
Muscle	0.026
Blood	0.000
Heart	0.000
Lung	0.012
Brain	0.005
Stomach	0.012
Sm Intes	51.549
Lg Intes	2.232

TABLE IV (see legend for Table III)

DATA	COUNTS	ORGAN	N ENTER WT	BCKG COR	%DOSE/G	% DOSE
1		Std A	X Rat 1 Wt	0		
1		Std B	X 235.14	0		
2	414367	Std C	av 413946	413946		
3	439	Bone	0.69	18	6.30E-03	1.09E.01
4	578	Tail	2.95	157	1.29E-02	3.79E-02
5	1232	Liver	11.96	811	1.64E-02	1.96E-01
6	1675	Kidney	2.51	1254	1.21E-01	3.03E-01
7	418	Spleen	0.66	0	0.00E+00	0.00E+00
8	423	Muscle	1.91	2	2.53E-04	2.56E-02
9	412	Blood	1.84	0	0.00E+00	0.00E+00
10	417	Heart	0.85	0	0.00E+00	0.00E+00
11	470	Lung	1.25	49	9.47E-03	1.18E-02
12	442	Brain	1.28	21	3.96E-03	5.07E-03
13	470	Stomach		49		1.18E-02
14	213806	Sm Intes		213385		5.15E+01
15	9661	Lg Intes		9240		2.23E+00
16	102818	Urine		102397		2.47E+01
17	12520	Urine		12099		2.92E+00
18	447	Urine		26		6.28E-03
19	421	BKG				

BKG AVG = 421

TABLE V

One Hour Biodistribution, Imaged Rat

TIME: One Hour biodistribution

DATE	LIGAND	METAL	COMMENTS
8/8/91	DOTPMB-K, D.	Sm=153	99% Complex

4:1, LIG:MET Molar Ratio (Metal = 3X10-4M)

	% DOSE/GRAM	% DOSE
WEIGHT: 263.82		
Bone	0.004	0.067
Tail	0.038	0.093
Liver	0.014	0.144
Kidney	0.084	0.245
Spleen	0.016	0.011
Muscle	0.001	0.078
Blood	0.001	0.019
Stomach		45.144
Smll Int		31.408
Lrg Int		0.003

TABLE VI

24 Hour Biodistribution, Imaged Rat
TIME: 24 Hour biodistribution

DATE	LIGAND	METAL	COMMENTS
8/8/91	DOTPMB-K	Sm=153	99% Complex

4:1, LIG:MET Molar Ratio (Metal = 3X10-4M)

	% DOSE/GRAM	% DOSE
WEIGHT: 263.82		
Bone	0.008	0.146
Tail	0.015	0.036
Liver	0.010	0.106
Kidney	0.154	0.451
Spleen	0.029	0.020
Muscle	0.017	1.883
Blood	0.000	0.004
Stomach		0.053
Sml1 Int		2.109
Sml1 Int		19.611
Lrg Int		8.351
Feces		35.981
Urine		2.799
Paper		0.126

TABLE VII

Rat Injected: 8/8/91
Time: 72 hour biodistribution

Date:	Ligand	Metal	Comments
8/12/91	DOTPMB-K	Sm-153	99% Complex

4:1, LIG:MET MOLAR RATIO (Metal = 3X10-4M)

	%DOSE/GRAM	% DOSE
WEIGHT: 269.58		
Bone	0.014	0.219
Tail	0.002	0.005
Liver	0.002	0.030
Kidney	0.019	0.054
Spleen	0.000	0.000
Muscle	0.000	0.000
Blood	0.000	0.000
Feces		5.832
Feces		5.467
Feces		2.464
Urine		0.077
Bladder		0.242

TABLE VIII

File=BTY15STD Summary Standardized Data Mouse #2 (15 minute biodistribution), 99% complex, 25.0 UL dose Ca added to complex at 1;1 molar, lig: Ca

DATE	LIGAND	METAL	COMMENTS
10/30/91	DOTPME-K	Sm-15	#08-07-91

2:1, Lig:Met Molar Ratio, (Metal=3x10-4M), pH 7-=8

%DOSE/GRAM			
	MOUSE 1	MOUSE 2	AVERAGE
WEIGHT	15.854	10.702	13.278
BONE	0.171	3.169	1.670
TAIL	1.374	83.296	42.335
LIVER	3.979	66.441	35.210
KIDNEY	0.889	14.568	7.728
SPLEEN	1.260	0.831	1.046
MUSCLE	0.173	1.437	0.805
BLOOD	43.105	3.743	23.424
HEART	0.472	2.418	1.445
LUNG	0.697	2.735	1.716
BRAIN	0.023	0.139	0.081
TUMOR	0.648	4.844	2.746
STOMACH	14.272	4.343	9.308
SMALL INT.	88.504	40.343	64.423
LARGE INT.	3.320	2.298	2.809
URINE	0.000	0.000	0.000
BODY 1	0.408	1.637	1.022
BODY 2	0.148	5.594	2.871
*MOUSE 2 DID NOT BECOME ACTIVE AFTER ANESTHESIA, HOWEVER ALIVE***			

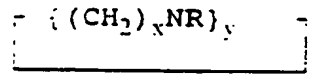
TABLE IX

	%DOSE	
	MOUSE 1	MOUSE 2
BONE	0.149	2.100
LIVER	3.379	37.732
KIDNEY	0.199	3.610
SPLEEN	0.095	0.039
MUSCLE	1.179	6.615
BLOOD	44.420	2.604
HEART	0.033	0.157
LUNG	0.090	0.210
BRAIN	0.010	0.054
TUMOR	0.062	0.237
STOMACH	3.565	0.586
SMALL INT.	86.734	27.837
LARGE INT.	2.994	1.145
URINE	12.857	0.007
BODY 1	2.294	6.890
BODY 2	0.585	17.147

Changes may be made in the construction, operation and arrangement of the various parts, elements, steps and procedures described herein without departing from the concept and scope of the invention as defined in the following claims.

CLAIMS

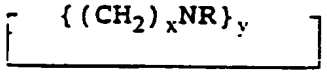
1. A polyazamacrocyclic compound or a salt thereof, the compound having the formula



where

x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;
y is 3 or 4;
R is $(CH_2)_zP(=O)OR^1OR^2$;
R^1 is H or CH_3;
R^2 is C_nH_{1+2n};
z is 1 to 3; and
n is 4 to 6.

2. A polyazamacrocyclic compound-metal complex having the formula



where

x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;
y is 3 or 4;
R is $(CH_2)_zP(=O)OR^1OR^2$;
R^1 is H or CH_3;
R^2 is C_nH_{1+2n};
z is 1 to 3;

r is 2 or 3;
M is a metal ion; and
n is 4 to 6.

3. The compound of claim 1 where y is 3.

4. The compound of claim 1 where y is 4.

5. The compound of claim 1 where y is 3 and x is 2.

6. The compound of claim 1 where y is 4 and x is 2.

7. The complex of claim 2 where y is 3.

8. The complex of claim 2 where y is 4.

9. The complex of claim 2 where y is 3 and x is 2.

10. The complex of claim 2 where y is 4 and x is 2.

11. The compound of claim 1 where y is 3, p is 1 and q is 2 or p is 2 and q is 1.

12. The complex of claim 2 where y is 3, p is 1 and q is 2 or p is 2 and q is 1.

13. The compound of claim 1 where y is 4, p is 1 and q is 3, p is 2 and q is 2 or p is 3 and q is 1.

14. The complex of claim 2 where y is 4, p is 1 and q is 3, p is 2 and q is 2 or p is 3 and q is 1.

15. The compound of claim 1 where z is 1.

16. The complex of claim 2 where z is 1.

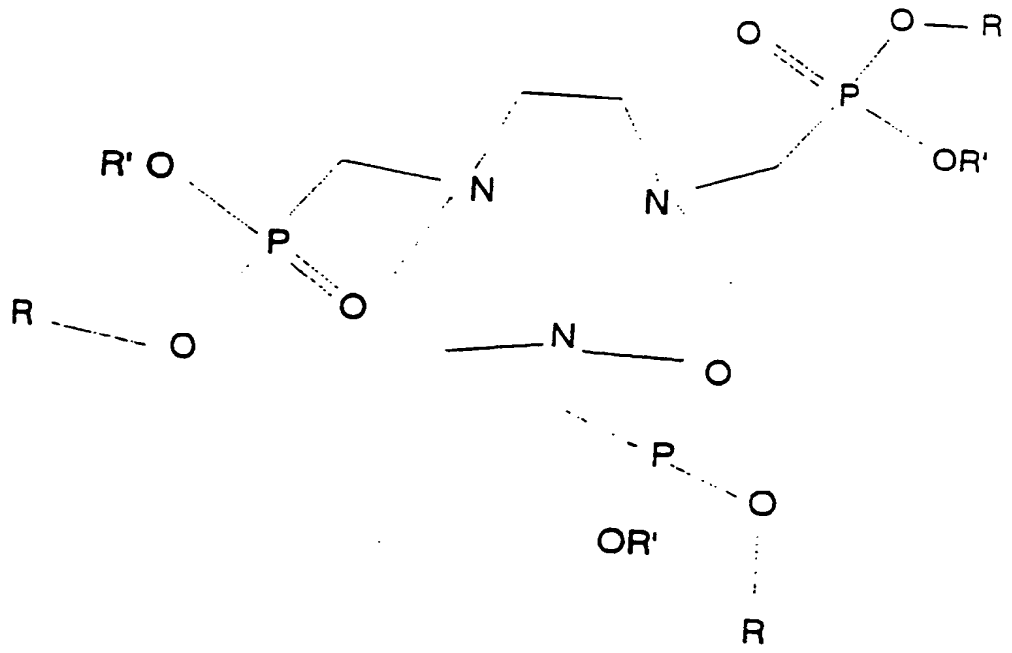
17. The compound of claim 1 where R^2 is C_4H_9.

18. The complex of claim 2 where R^2 is C_4H_9.

19. The complex of claim 2 where M is a lanthanide element.

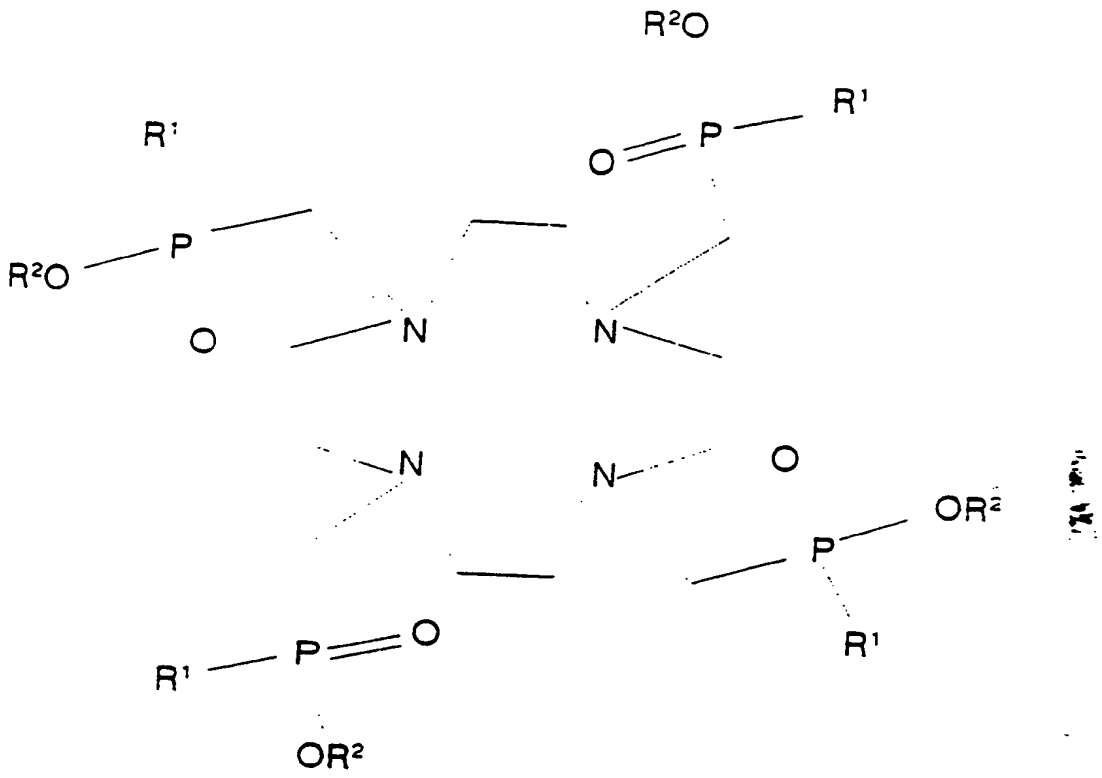
20. The complex of claim 2 where M^{+r} is Gd^{+3}.

21. A compound or salt thereof, the compound having the formula:



where R is C_nH_{1+2n};
n is 4 to 6; and
R' is H.

22. A compound or salt thereof, the compound having the formula:

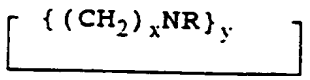


where R^1 is OC_nH_{1+2n};
n is 4 to 6; and
R^2 is H.

23. The compound of claim 21 or 22 where n is 4.

24. A method for increasing contrast of nuclear magnetic resonance images of a patient, the method comprising

administering to a patient needing nuclear magnetic resonance imaging a polyazamacrocyclic compound or a salt thereof, the compound having the formula



where

x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;

y is 3 or 4;

R is $(CH_2)_zP(=O)OR^1OR^2$;

R^1 is H or CH_3;

R^2 is C_nH_{1+2n};

n is 4 to 6;

z is 1 to 3;

r is 2 or 3; and

M is a metal ion; and

obtaining a magnetic resonance image of the patient.

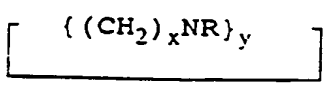
25. The method of claim 24 wherein x is 2, y is 3, z is 1, and n is 4.

26. The method of claim 24 wherein x is 2, y is 4, z is 1, and n is 4.

27. The method of claim 24 wherein M is a lanthanide element.

28. The method of claim 24 wherein M is Gd^{+3}.

29. A method for enhancing an x-ray image of a subject, the method comprising administering to the subject a polyazamacrocyclic compound-metal complex having the formula

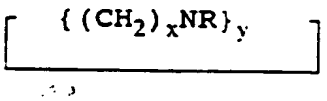


where

x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;
y is 3 or 4;
R is $(CH_2)_ZP(=O)OR^1OR^2$;
R^1 is H or CH_3;
R^2 is C_nH_{1+2n};
n is 4 to 6;
z is 1 to 3;
M is a heavy metal; and
r is 2 or 3; and

obtaining a magnetic resonance image of said subject.

30. A method for enhancing a scintigraphic image of a subject, the method comprising administering to the subject a polyazamacrocyclic compound-metal complex having the formula



where

x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;
y is 3 or 4;
R is $(CH_2)_ZP(=O)OR^1OR^2$;
R^1 is H or CH_3;
R^2 is C_nH_{1+2n};
z is 1 to 3;

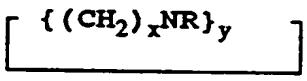
M is a radionuclide metal; and
r is 2 or 3; and
obtaining a scintigraphic image of said subject.

31. The method of claim 30 wherein M is samarium 153.

32. The method of claim 29 or 30 wherein x is 2, y is 3, z is 1, and n is 4.

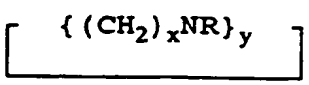
33. The method of claim 29 or 30 wherein x is 2, y is 4 z is 1, and n is 4.

34. A polyazamacrocyclic compound or a salt thereof, the compound having the formula



where
x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;
y is 3 or 4
R is $(CH_2)_ZP(=O)OR^1OR^2$;
R^1 is H;
R^2 is C_4H_9; and
z is 1 to 3.

35. A polyazamacrocyclic compound-metal complex having the formula



where

x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;
y is 3 or 4;
R is $(CH_2)_zP(=O)OR^1OR^2$;
R^1 is H;
R^2 is C_4H_9;
z is 1 to 3;
r is 2 or 3; and
M is a metal ion.

36. A method for increasing contrast of nuclear magnetic resonance images of a patient, the method comprising

administering to a patient needing nuclear magnetic resonance imaging a polyazamacrocyclic compound or a salt thereof, the compound having the formula

$$\left[\{(CH_2)_xNR\}_y\right]M^{+r}$$

where

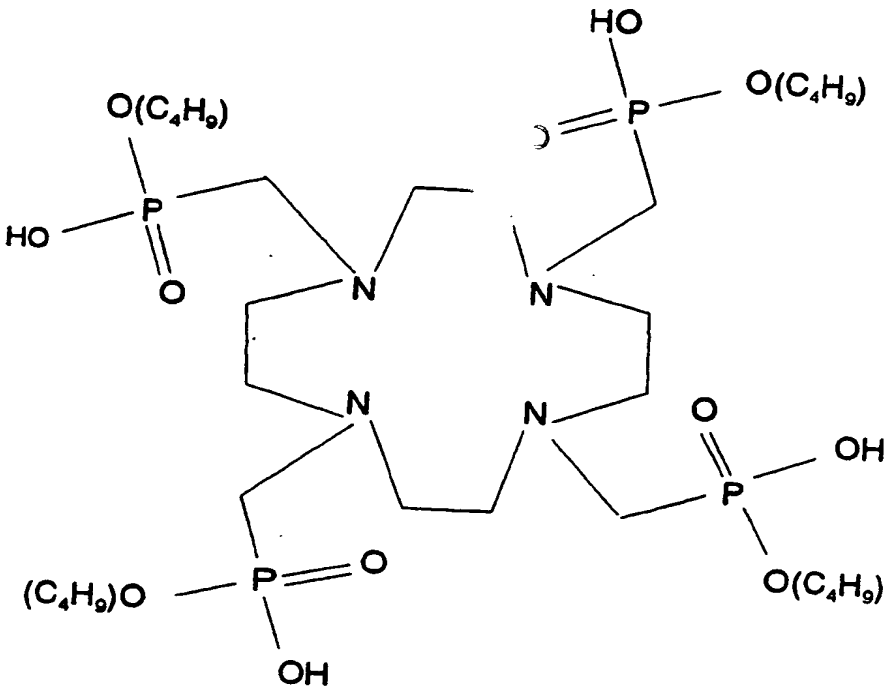
x is 2, 3 or a combination of p 2(s) and q 3(s) where p + q = y;
y is 3 or 4;
R is $(CH_2)_zP(=O)OR^1OR^2$;
R^1 is H;
R^2 is C_4H_9;
z is 1 to 3;
r is 2 or 3; and
M is a metal ion; and

obtaining a magnetic resonance image of the patient.

37. The complex of claim 35 where M^{+r} is Gd^{+3}.

38. The method of claim 36 where M^{+r} is Gd^{+3}.

39. A compound or salt thereof, the compound having the formula:



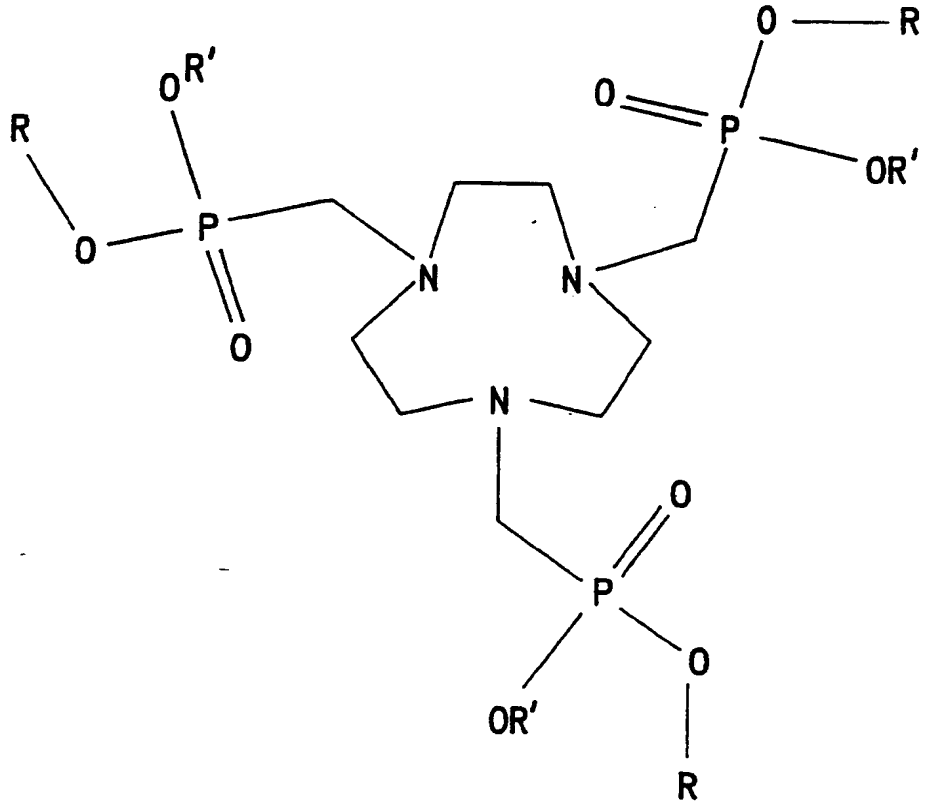


FIG. 1

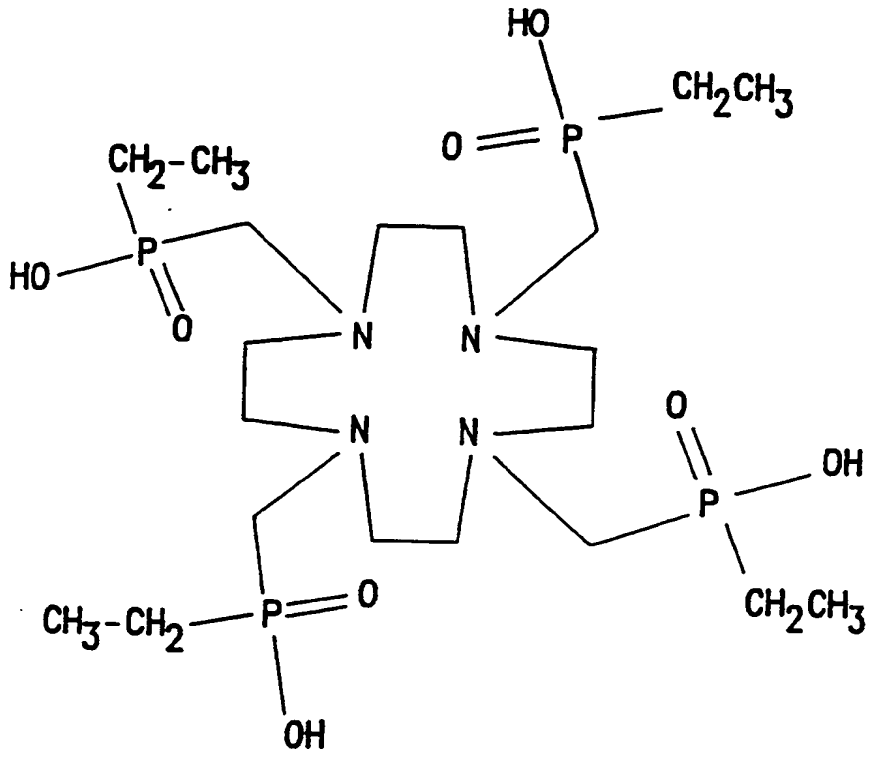


FIG.2

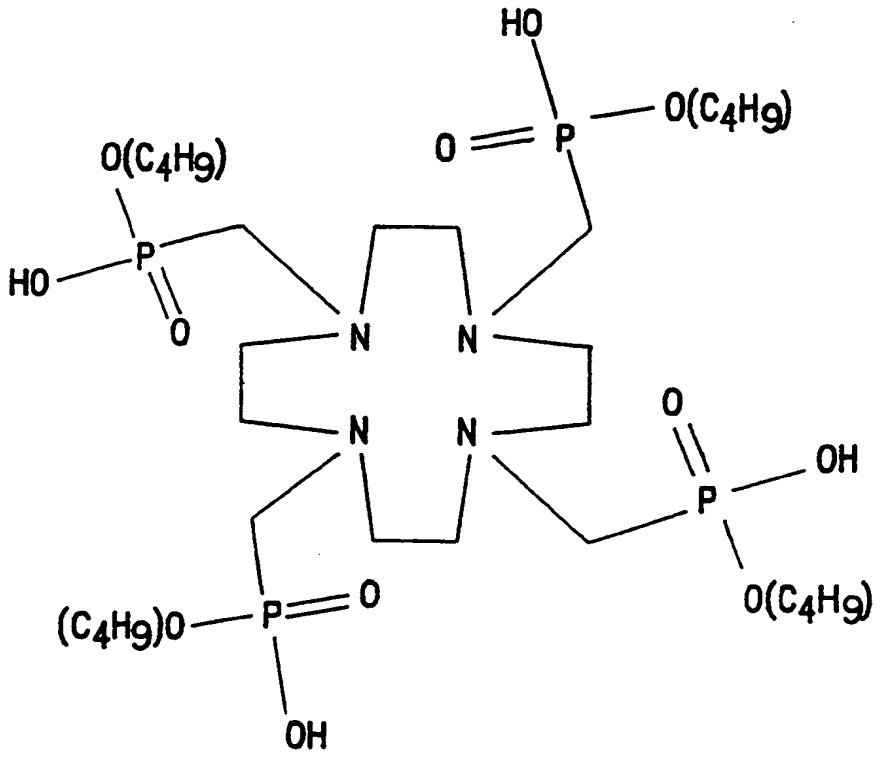


FIG.3

INTERNATIONAL SEARCH REPORT

International Application. PCT/US 93/06158

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)*

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 C07F9/6515; A61K49/00; C07F9/6524

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	C07F ; A61K

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	WO,A,9 208 725 (BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM) 29 May 1992 see page 5, line 1 - line 27; claims 17,18	1-39
A	JOURNAL OF THE CHEMICAL SOCIETY, CHEMICAL COMMUNICATIONS 1991, LETCHWORTH GB pages 1252 - 1253 ISTVAN LAZAR 'N,N',N''-Tris(methoxymethyl) -1,4,7-triazacyclononane: a New Synthetic Tool for the Synthesis of Tris-N-substituted 1,4,7-Triazacyclononane Derivatives'	

* Special categories of cited documents : [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
22 SEPTEMBER 1993	01. 10. 93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	BESLIER L.M.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

US 9306158
SA 76662

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9208725	29-05-92	AU-A-	9077091	11-06-92
		CN-A-	1066073	11-11-92
		EP-A-	0558661	08-09-93
		US-A-	5188816	23-02-93

EP FORM P079

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82